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Keywords: Geophysics, Rock unit, Borehole, Deformation zone, Fractures, Alteration.

Abstract

This report contains geological single-hole interpretation of the cored boreholes KLX22A–B, KLX23A–B, KLX24A, KLX25A and KLX26A–B at Laxemar. The interpretation combines the geological core mapping, interpreted geophysical logs and borehole radar measurements to identify rock units and possible deformation zones in the boreholes.

The geological single-hole interpretation shows that one rock unit (RU1) occurs in KLX22A. In general, borehole KLX22A is dominated by quartz monzodiorite (501036). Subordinate rock types comprise occurrences of fine-grained granite (511058) and fine-grained diorite-gabbro (505102). One possible deformation zone is identified in KLX22A (DZ1).

Borehole KLX22B is dominated by quartz monzodiorite (501036), which constitutes one rock unit in the borehole (RU1). Subordinate rock types comprise occurrences of fine-grained granite (511058), fine-grained diorite-gabbro (505102), Ävrö granite (501044), very sparse occurrence of diorite/gabbro (501033), pegmatite (501061) and presumed sandstone (506007). One possible deformation zone is identified in KLX22B (DZ1).

One rock unit (RU1) occurs in KLX23A. In general, the rock unit is dominated by quartz monzodiorite (501036). Subordinate rock types comprise occurrences of fine-grained granite (511058) and very sparse occurrence of pegmatite (501061). Two possible deformation zones are identified in KLX23A (DZ1–DZ2).

Borehole KLX23B is dominated by quartz monzodiorite (501036), which constitutes one rock unit in the borehole (RU1). Subordinate rock types comprise occurrences of fine-grained granite (511058), Ävrö granite (501044), and very sparse occurrence of granite (501058). One possible deformation zone is identified in KLX23B (DZ1).

The geological single-hole interpretation shows that one rock unit (RU1) occurs in KLX24A. The rock unit is dominated by quartz monzodiorite (501036). Subordinate rock types comprise occurrences of fine-grained granite (511058), pegmatite (501061), diorite/gabbro (501033) and very sparse occurrences of granite (501058) and presumed sandstone (506007). Four possible deformation zones are identified in KLX24A (DZ1–DZ4).

Borehole KLX25A is dominated by quartz monzodiorite (501036), which constitutes one rock unit in the borehole (RU1). Subordinate rock types comprise occurrences of pegmatite (501061) and fine-grained diorite-gabbro (505102). One possible deformation zone is identified in KLX25A (DZ1).

Two rock units (RU1–RU2) occur in KLX26A. However, due to the repetition of RU1 (RU1a and RU1b) the borehole can be divided into three sections. In general, the borehole is dominated by diorite/gabbro (501033) and a section of fine-grained granite (511058). Subordinate rock types comprise occurrences of Ävrö granite (501044), pegmatite (501061), fine-grained diorite-gabbro (505102) and granite (501058). Four possible deformation zones are identified in KLX26A (DZ1–DZ4).

The geological single-hole interpretation shows that two rock units (RU1–RU2) occur in KLX26B. However, due to the repetition of RU1 (RU1a and RU1b) the borehole can be divided into three sections. The borehole is dominated by diorite/gabbro (501033) and quartz monzodiorite (501036). Subordinate rock types comprise occurrences of fine-grained granite (511058) and pegmatite (501061). No possible deformation zones are identified in KLX26B.

Sammanfattning

Denna rapport behandlar geologisk enhålstolkning av kärnborrhålen KLX22A–B, KLX23A–B, KLX24A, KLX25A och KLX26A–B i Laxemar. Den geologiska enhålstolkningen syftar till att utifrån den geologiska karteringen, tolkade geofysiska loggar och borrhålsradarmätningar identifiera olika litologiska enheters fördelning i borrhålen samt möjliga deformationszoners läge och utbredning.

Den geologiska enhålstolkningen visar att KLX22A består av en litologisk enhet (RU1). Generellt sett domineras den litologiska enheten av kvartsmonzodiorit (501036). Finkornig granit (511058) och finkornig diorit-gabbro (505102) förekommer som underordnade bergarter. En möjlig deformationszon har identifierats i KLX22A (DZ1).

Borrhål KLX22B domineras av kvartsmonzodiorit (501036), vilken utgör en litologisk enhet i borrhålet (RU1). Finkornig granit (511058), finkornig diorit-gabbro (505102), Ävrögranit (501044) och mindre förekomster av diorit/gabbro (501033), pegmatit (501061) och förmodad sandsten (506007) förekommer som underordnade bergarter. En möjlig deformationszon har identifierats i KLX22B (DZ1).

En litologisk enhet (RU1) förekommer i KLX23A. Generellt domineras den litologiska enheten av kvartsmonzodiorit (501036). Finkornig granit (511058) och små förekomster av pegmatit (501061) förekommer som underordnade bergarter. Två möjliga deformationszoner har identifierats i KLX23A (DZ1–DZ2).

Den geologiska enhålstolkningen visar att KLX24A består av en litologisk enhet (RU1). Generellt sett domineras den litologiska enheten av kvartsmonzodiorit (501036). Finkornig granit (511058), pegmatit (501061), diorit/gabbro (501033) och små förekomster av granit (501058) och förmodad sandsten (506007) förekommer som underordnade bergarter. Fyra möjliga deformationszoner har identifierats i KLX24A (DZ1–DZ4).

Borrhål KLX25A domineras av kvartsmonzodiorit (501036), vilken utgör en litologisk enhet i borrhålet (RU1). Pegmatit (501061) och finkornig diorit-gabbro (505102) förekommer som underordnade bergarter. En möjlig deformationszon har identifierats i KLX25A (DZ1).

Två litologiska enheter (RU1–RU2) förekommer i KLX26A. Baserat på repetition av RU1 (RU1a och RU1b) kan borrhålet delas in i tre sektioner. Borrhålet domineras av diorit/gabbro (501033) och en sektion med finkornig granit (511058). Ävrögranit (501044), pegmatit (501061), finkornig diorit-gabbro (505102) och granit (501058) förekommer som underordnade bergarter. Fyra möjliga deformationszoner har identifierats i KLX26A (DZ1–DZ4).

Den geologiska enhålstolkningen visar att KLX26B består av två litologiska enheter (RU1–RU2). Baserat på repetition av RU1 (RU1a och RU1b) kan borrhålet delas in i tre sektioner. Borrhålet domineras av diorit/gabbro (501033) och kvartsmonzodiorit (501036). Finkornig granit (511058) och pegmatit (501061) förekommer som underordnade bergarter. Inga möjliga deformationszoner har identifierats i KLX26B.

Contents

1 Introduction

Much of the primary geological and geophysical borehole data stored in the SKB database SICADA need to be integrated and synthesized before they can be used for modeling in the 3D-CAD system Rock Visualization System (RVS). The end result of this procedure is a geological single-hole interpretation, which consists of integrated series of different loggings and accompanying descriptive documents (SKB MD 810.003 v. 3.0, SKB internal controlling document).

This document reports the results gained by the geological single-hole interpretation of boreholes KLX22A–B, KLX23A–B, KLX24A, KLX25A and KLX26A–B at Laxemar (Figure 1-1), which is one of the activities performed within the site investigation at Oskarshamn. The work was carried out in accordance with activity plan AP PS 400-06-128. The controlling documents for performing this activity are listed in Table 1-1. Both activity plan and method description are SKB's internal controlling documents. Rock type nomenclature that has been used is shown in Table 1-2.

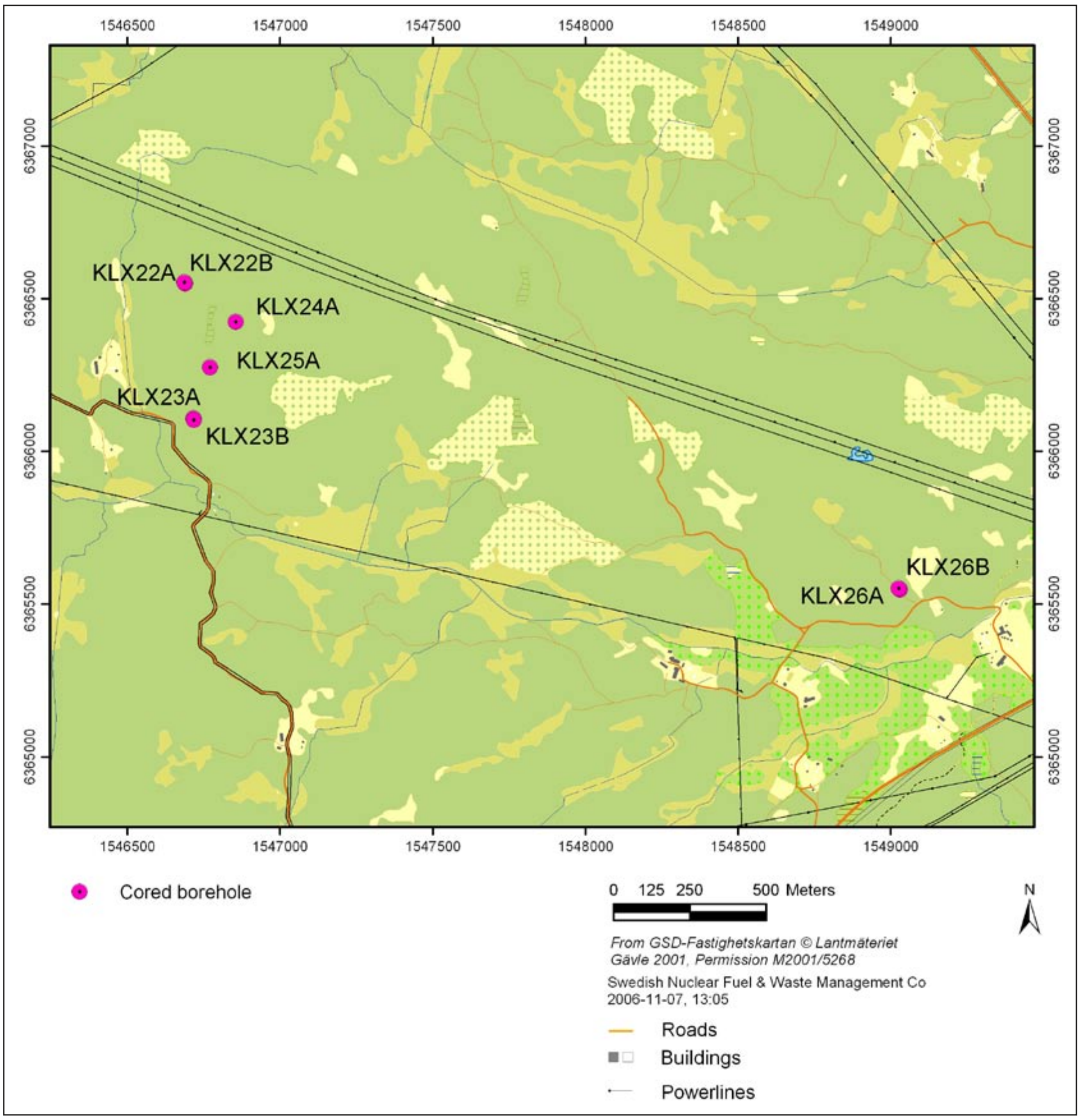


Figure 1-1. Map showing the position of the core boreholes KLX22A–B, KLX23A–B, KLX24A, KLX25A and KLX26A–B.

Table 1-1. Controlling documents for the performance of the activity.

Activity plan	Number	Version
Geologisk enhålstolkning av KLX22A–B, KLX23A–B, KLX24A, KLX25A och KLX26A–B	AP PS 400-06-128	1.0
Method description	**Number**	**Version**
Metodbeskrivning för geologisk enhålstolkning	SKB MD 810.003	3.0

Table 1-2. Rock type nomenclature for the site investigation at Oskarshamn.

Rock type	Rock code	Rock description
Dolerite	501027	Dolerite
Fine-grained Götemar granite	531058	Granite, fine- to medium-grained, ("Götemar granite")
Coarse-grained Götemar granite	521058	Granite, coarse-grained, ("Götemar granite")
Fine-grained granite	511058	Granite, fine- to medium-grained
Pegmatite	501061	Pegmatite
Granite	501058	Granite, medium- to coarse-grained
Ävrö granite	501044	Granite to quartz monzodiorite, generally porphyritic
Quartz monzodiorite	501036	Quartz monzonite to monzodiorite, equigranular to weakly porphyritic
Diorite/gabbro	501033	Diorite to gabbro
Fine-grained dioritoid	501030	Intermediate magmatic rock
Fine-grained diorite-gabbro	505102	Mafic rock, fine-grained
Sulphide mineralization	509010	Sulphide mineralization
Sandstone	506007	Sandstone

Original data from the reported activity are stored in the primary database Sicada, where they are traceable by the Activity Plan number (AP PS 400-06-128). Only data in SKB's databases are accepted for further interpretation and modelling. The data presented in this report are regarded as copies of the original data. Data in the databases may be revised, if needed. Such revisions will not necessarily result in a revision of the P-report, although the normal procedure is that major data revisions entail a revision of the P-report. Minor data revisions are normally presented as supplements, available at www.skb.se.

2 Objective and scope

A geological single-hole interpretation is carried out in order to identify and to describe briefly the characteristics of major rock units and possible deformation zones within a borehole. The work involves an integrated interpretation of data from the geological mapping of the borehole (Boremap), different borehole geophysical logs and borehole radar data. The geological mapping of the cored boreholes involves a documentation of the character of the bedrock in the drill core. This work component is carried out in combination with an inspection of the oriented image of the borehole walls that is obtained with the help of the Borehole Image Processing System (BIPS). The interpretations of the borehole geophysical and radar logs are available when the single-hole interpretation is performed. The result from the geological single-hole interpretation is presented in a WellCad plot. The work reported here concerns stage 1 in the single-hole interpretation, as defined in the method description.

3 Data used for the geological single-hole interpretation

The following data have been used in the single-hole interpretation of boreholes KLX22A–B, KLX23A–B, KLX24A, KLX25A and KLX26A–B:

- Boremap data (including BIPS and geological mapping data) /2, 3, 4/
- Generalized geophysical logs and their interpretation /5/
- Radar data and their interpretation /6/

As a basis for the geological single-hole interpretation a combined WellCad plot consisting of the above mentioned data sets were used. An example of a WellCad plot used during the geological single-hole interpretation is shown in Figure 3-1. The plot consists of nine main columns and several subordinate columns. These include nine main:

1: Length along the borehole

2: Boremap data
- 2.1: Rock type
- 2.2: Rock type < 1 m
- 2.3: Rock type structure
- 2.4: Rock structure intensity
- 2.5: Rock type texture
- 2.6: Rock type grain size
- 2.7: Structure orientation
- 2.8: Rock alteration
- 2.9: Rock alteration intensity
- 2.10: Crush

3: Generalized geophysical data
- 3.1: Silicate density
- 3.2: Magnetic susceptibility
- 3.3: Natural gamma radiation
- 3.4: Estimated fracture frequency

4: Unbroken fractures
- 4.1: Primary mineral
- 4.2: Secondary mineral
- 4.3: Third mineral
- 4.4: Fourth mineral
- 4.5: Alteration, dip direction

5: Broken fractures
- 5.1: Primary mineral
- 5.2: Secondary mineral
- 5.3: Third mineral
- 5.4: Fourth mineral
- 5.5: Aperture (mm)
- 5.6: Roughness
- 5.7: Surface
- 5.8: Slickenside
- 5.9: Alteration, dip direction

6: Crush zones
   6.1: Piece (mm)
   6.2: Sealed network
   6.3: Core loss

7: Fracture frequency
   7.1: Sealed fractures
   7.2: Open fractures

8: BIPS

9: Length along the borehole

The geophysical logs are described below:

Magnetic susceptibility: The rock has been classified into sections of low, medium, high, and very high magnetic susceptibility. The susceptibility is strongly connected to the magnetite content in the different rock types.

Natural gamma radiation: The rock has been classified into sections of low, medium, and high natural gamma radiation. Low radiation may indicate mafic rock types and high radiation may indicate younger, fine- to medium-grained granite or pegmatite.

Possible alteration: This parameter has not been used in the geological single-hole interpretation in the area.

Silicate density: This parameter indicates the density of the rock after subtraction of the magnetic component. It provides general information on the mineral composition of the rock types, and serves as a support during classification of rock types.

Estimated fracture frequency: This parameter provides an estimate of the fracture frequency along 5 m sections, calculated from short and long normal resistivity, SPR, P-wave velocity as well as focused resistivity 140 and 300. The estimated fracture frequency is based on a statistical connection after a comparison has been made between the geophysical logs and the mapped fracture frequency. The log provides an indication of sections with low and high fracture frequencies.

Close inspection of the borehole radar data was carried out during the interpretation process, especially during the identification of possible deformation zones. The occurrence and orientation of radar anomalies within the possible deformation zones are commented upon in the text that describes these zones.

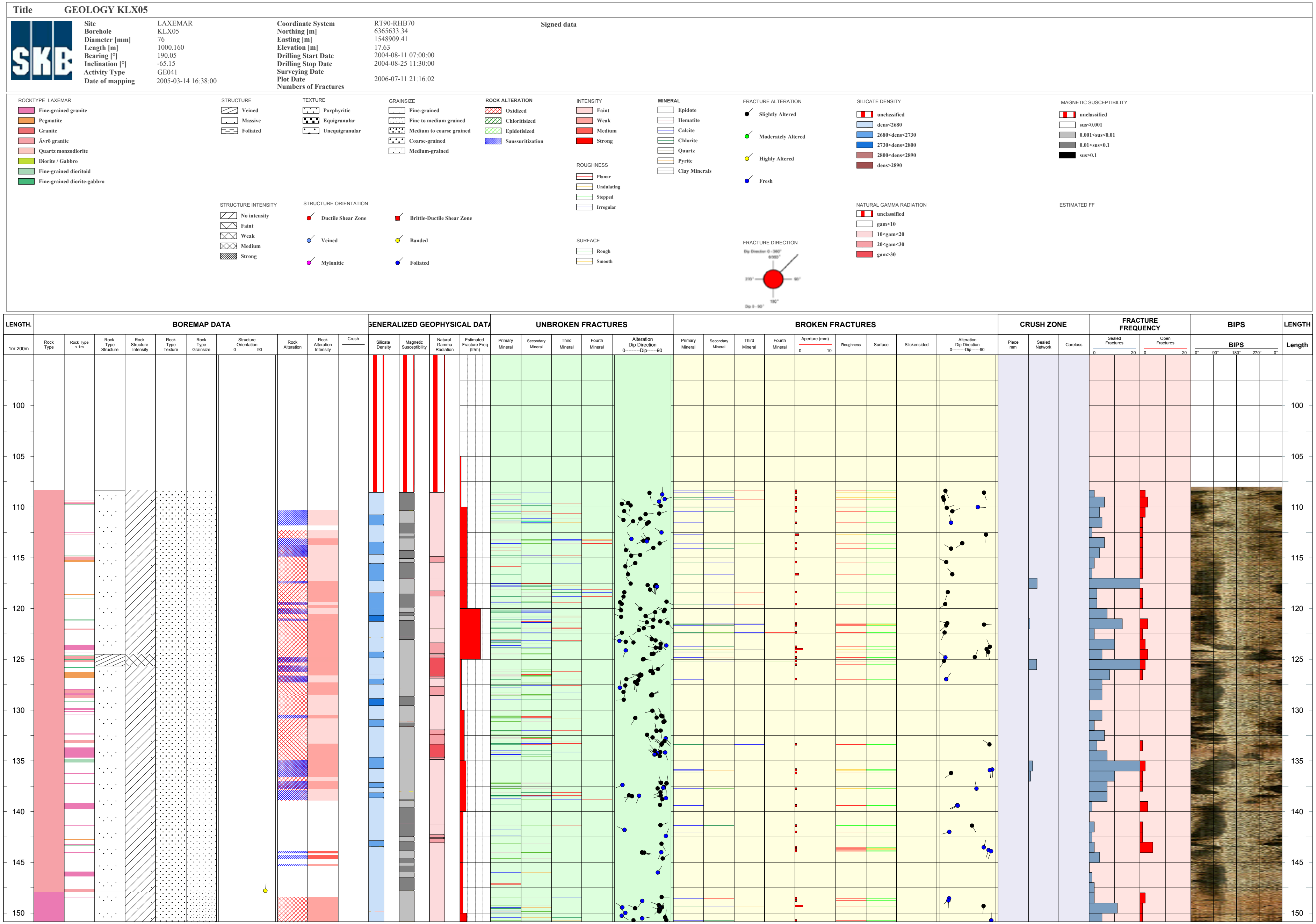


Figure 3-1. Example of WellCad plot (from borehole KLX05 in Laxemar) used as a basis for the single-hole interpretation.

4 Execution

4.1 General

The geological single-hole interpretation has been carried out by a group of geoscientists consisting of both geologists and geophysicists. All data to be used (see Chapter 3) are visualized side by side in a borehole document extracted from the software WellCad. The working procedure is summarized in Figure 4-1 and in the text below.

The first step in the working procedure is to study all types of data (rock type, rock alteration, silicate density, natural gamma radiation, etc) related to the character of the rock type and to merge sections of similar rock types, or sections where one rock type is very dominant, into rock units (minimum length of c 5 m). Each rock unit is defined in terms of the borehole length interval and provided with a brief description for inclusion in the WellCad plot. This includes a brief description of the rock types affected by the possible deformation zone. The confidence in the interpretation of a rock unit is made on the following basis: 3 = high, 2 = medium and 1 = low.

The second step in the working procedure is to identify possible deformation zones by visual inspection of the results of the geological mapping (fracture frequency, fracture mineral, aperture, alteration, etc) in combination with the geophysical logging and radar data. The section of each identified possible deformation zone is defined in terms of the borehole length interval and provided with a brief description for inclusion in the WellCad plot. The confidence in the interpretation of a possible deformation zone is made on the following basis: 3 = high, 2 = medium and 1 = low.

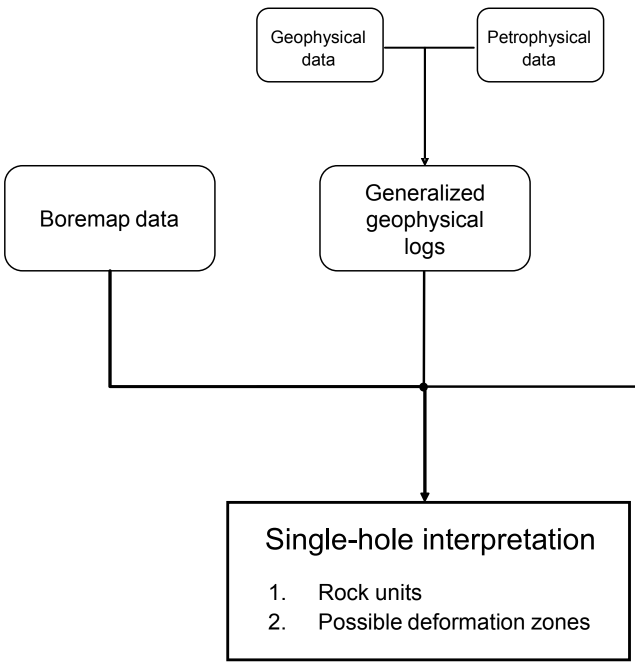


Figure 4-1. *Schematic block-scheme of single-hole interpretation.*

Inspection of BIPS images is carried out whenever it is judged necessary during the working procedure. Furthermore, following definition of rock units and deformation zones, with their respective confidence estimates, the drill cores are inspected in order to check the selection of the boundaries between these geological entities. If judged necessary, the location of these boundaries is adjusted.

Possible deformation zones that are ductile or brittle in character have been identified primarily on the basis of occurrence of protomylonitic to mylonitic foliation and the frequency of fractures, respectively, according to the recommendations in /1/. Both the transitional parts and the core part have been included in each zone (Figures 4-2 to 4-4). The fracture/m values in Figure 4-4 may serve only as examples. The frequencies of open and sealed fractures have been assessed in the identification procedure, and the character of the zone has been described accordingly. Partly open fractures are included together with open fractures in the brief description of each zone. The presence of bedrock alteration, the occurrence and, locally, inferred orientation of radar reflectors, the resistivity, SPR, P-wave velocity, caliper and magnetic susceptibility logs have all assisted in the identification of primarily the brittle structures.

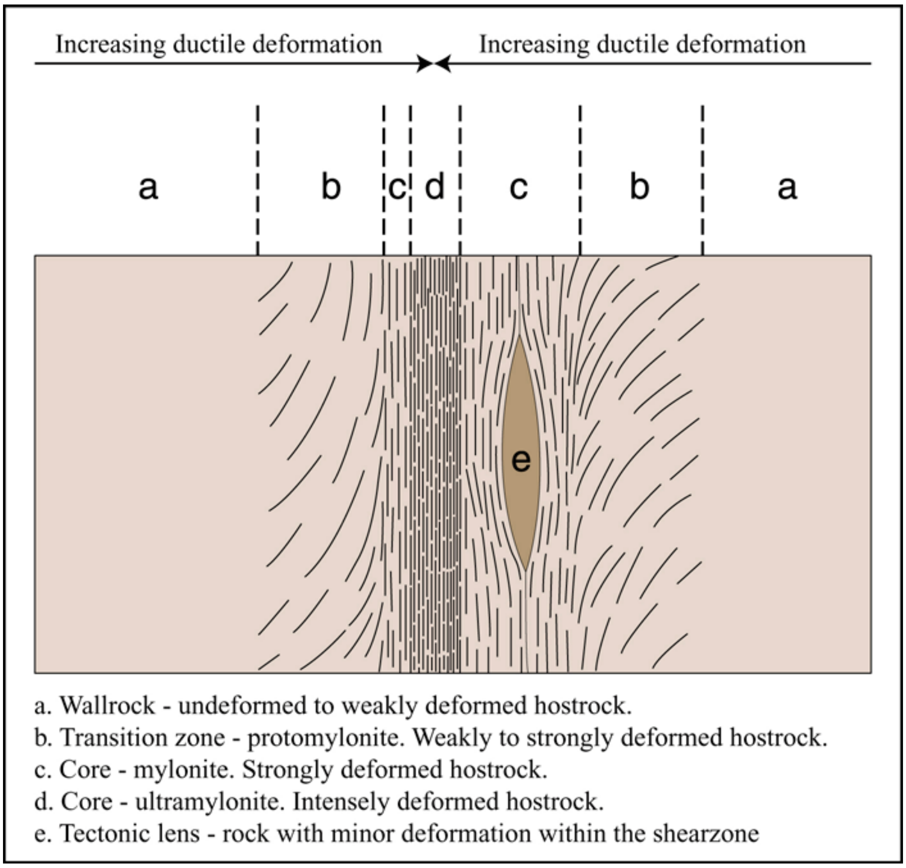


Figure 4-2. *Schematic example of a ductile shear zone. Homogeneous rock which is deformed under low- to medium-grade metamorphic conditions (after /1/).*

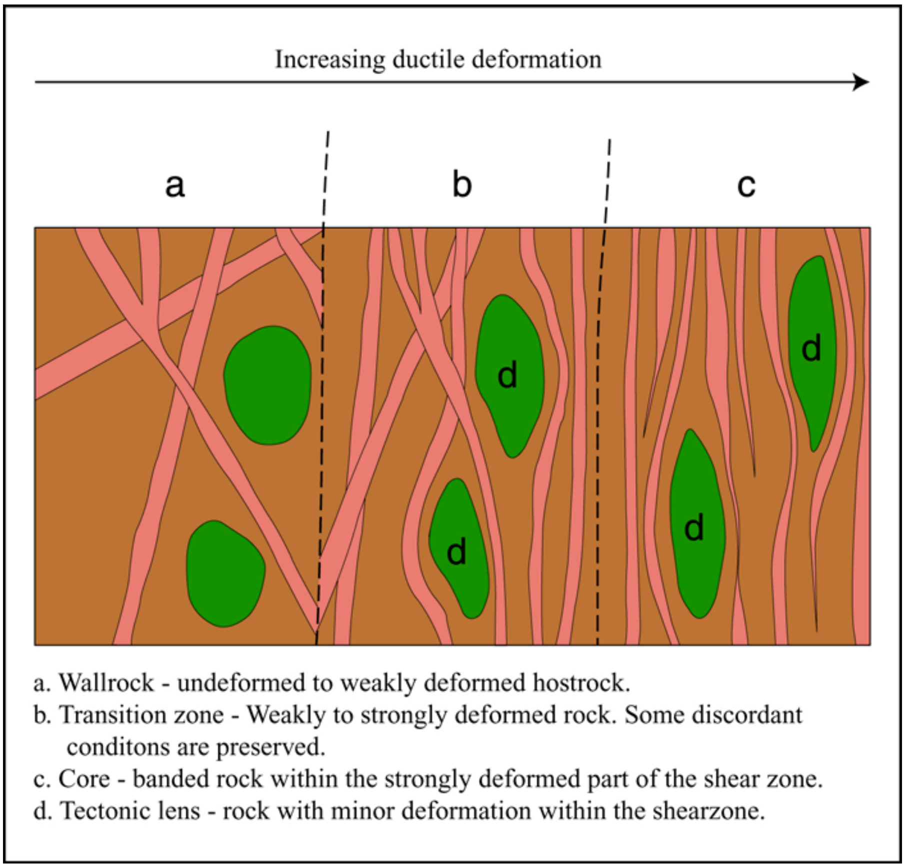


Figure 4-3. *Schematic example of a ductile shear zone. Heterogeneous rock which is deformed under low- to high-grade metamorphic conditions (after /1/).*

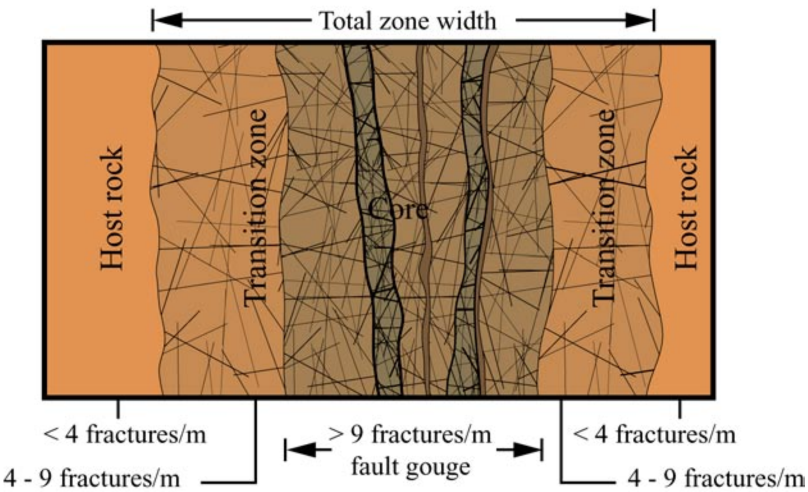


Figure 4-4. *Schematic example of a brittle deformation zone (after /1/).*

Since the frequency of fractures is of key importance for the definition of the possible deformation zones, a moving average plot for this parameter is shown for the core boreholes KLX22A–B, KLX23A–B, KLX24A, KLX25A and KLX26A–B (Figures 4-5 to 4-12). A 5 m window and 1 m steps have been used in the calculation procedure. The moving averages for open fractures alone, the total number of open fractures (open, partly open and crush), the sealed fractures alone, and the total number of sealed fractures (sealed and sealed fracture network) are shown in a diagram.

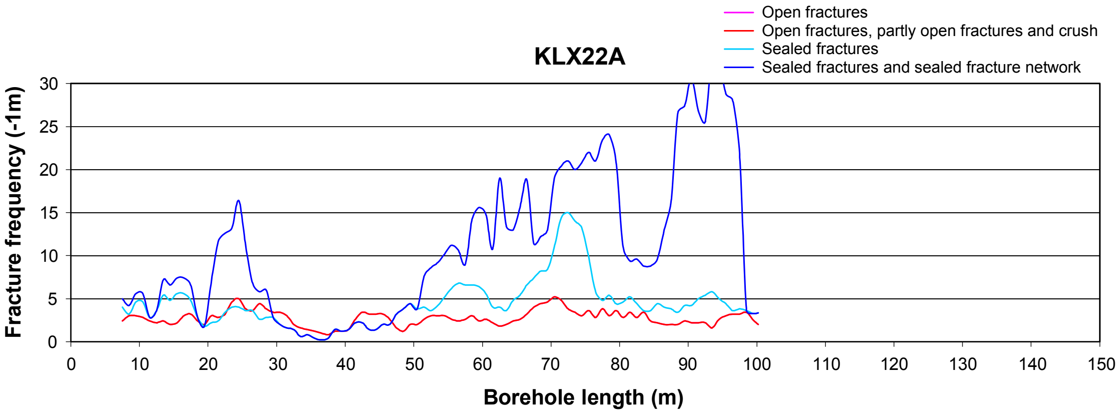


Figure 4-5. *Fracture frequency plot for KLX22A. Moving average with a 5 m window and 1 m steps.*

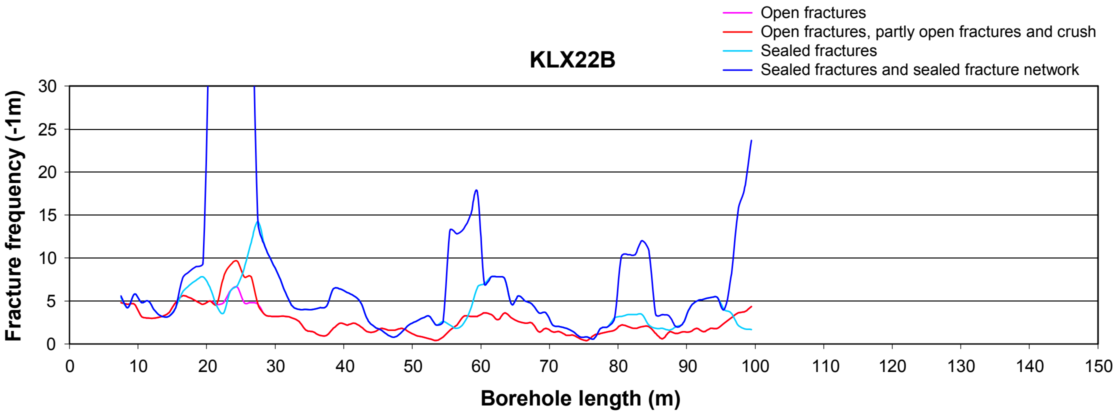


Figure 4-6. *Fracture frequency plot for KLX22B. Moving average with a 5 m window and 1 m steps.*

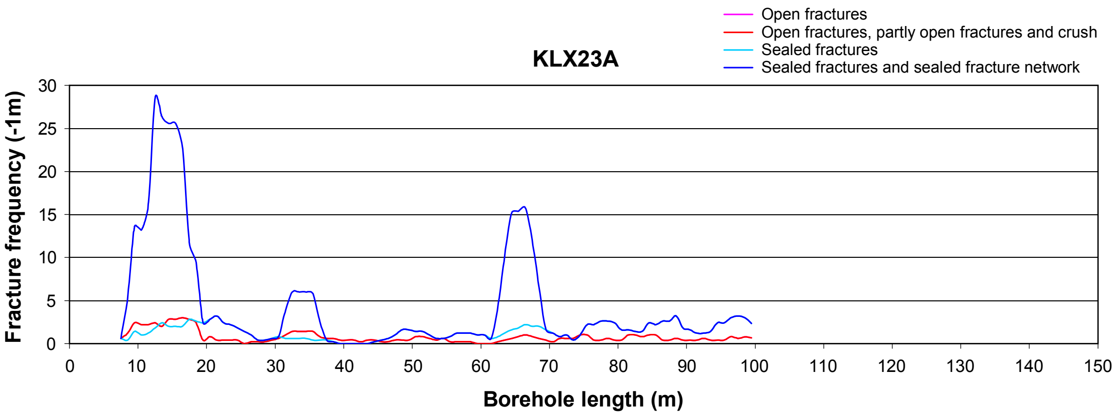


Figure 4-7. *Fracture frequency plot for KLX23A. Moving average with a 5 m window and 1 m steps.*

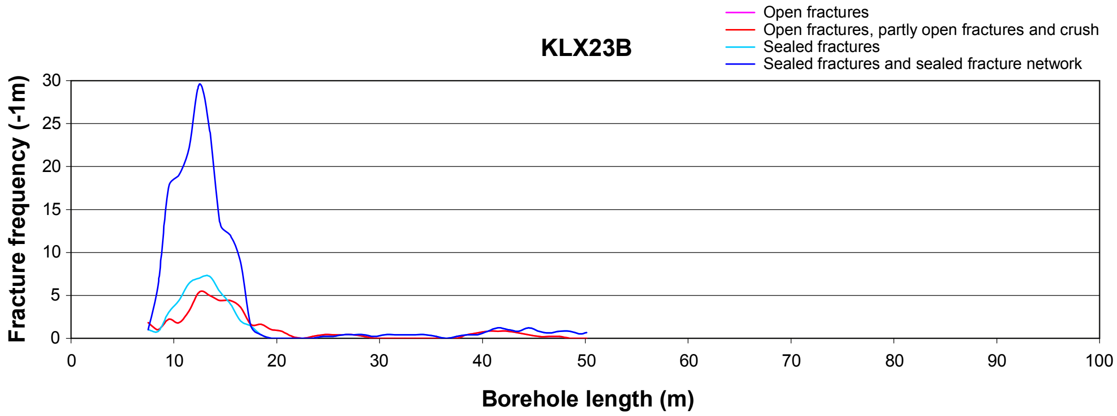


Figure 4-8. Fracture frequency plot for KLX23B. Moving average with a 5 m window and 1 m steps.

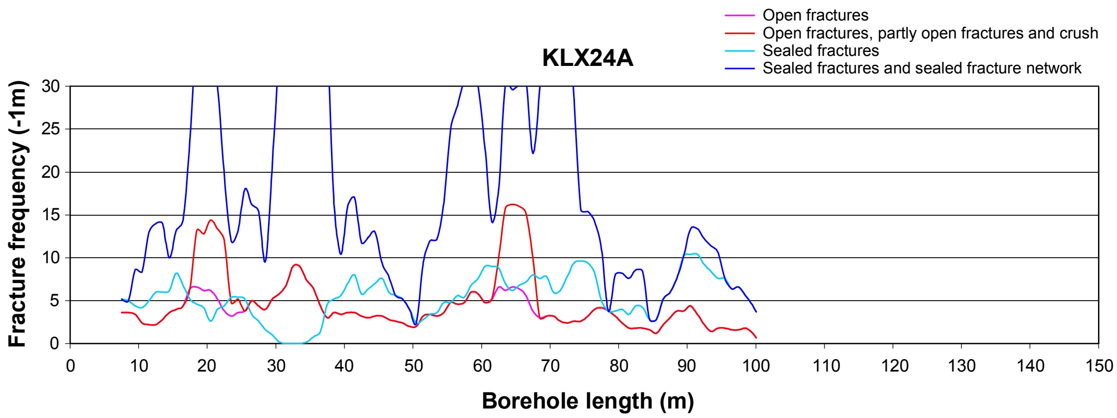


Figure 4-9. Fracture frequency plot for KLX24A. Moving average with a 5 m window and 1 m steps.

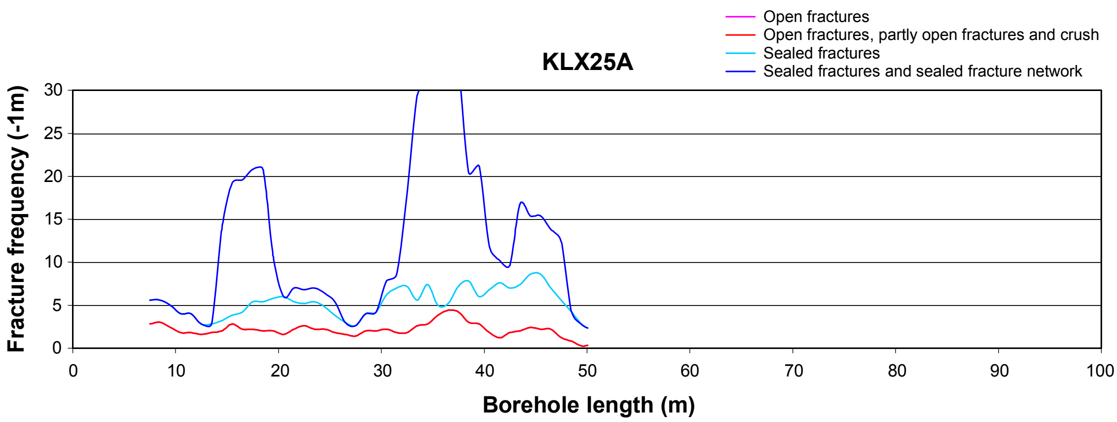


Figure 4-10. Fracture frequency plot for KLX25A. Moving average with a 5 m window and 1 m steps.

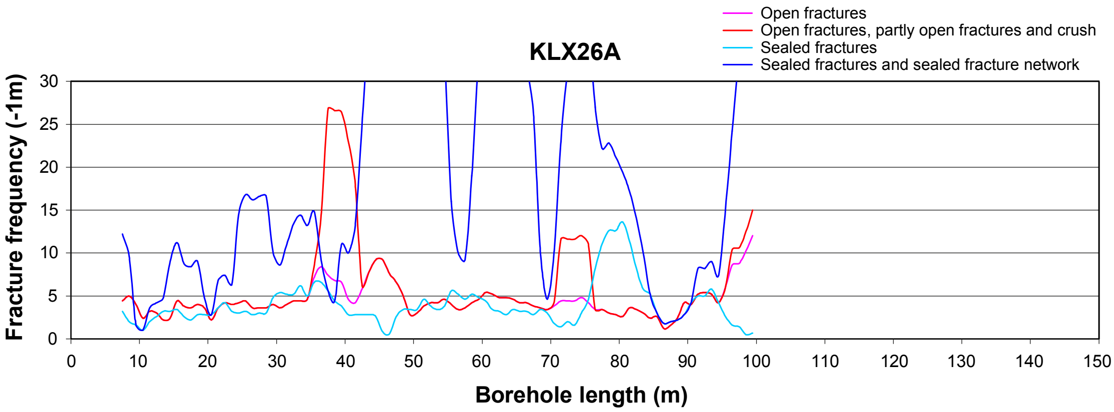


Figure 4-11. *Fracture frequency plot for KLX26A. Moving average with a 5 m window and 1 m steps.*

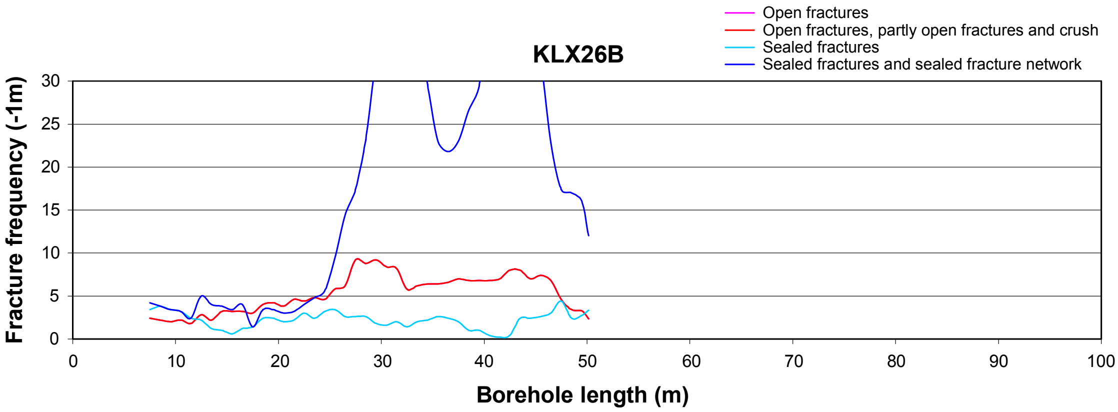


Figure 4-12. *Fracture frequency plot for KLX26B. Moving average with a 5 m window and 1 m steps.*

The occurrence and orientation of radar anomalies within these possible deformation zones are used during the identification of zones. Overview of the borehole radar measurement in KLX22A–B, KLX23A–B, KLX24A, KLX25A and KLX26A–B is shown in Figures 4-13 to Figure 4-20. In some cases, alternative orientations for oriented radar reflectors are presented. One of the alternatives is considered to be correct, but due to uncertainty in the interpretation of radar data, a decision concerning which of the alternatives that represent the true orientation cannot be made.

Orientations from directional radar are presented as strike/dip using the right-hand-rule method, e.g. 040/80 corresponds to a strike of N40°E and a dip of 80° to the SE.

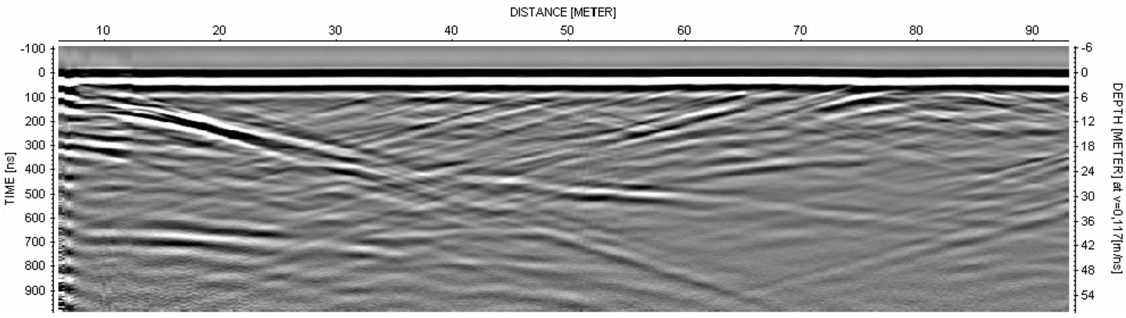


Figure 4-13. *Overview (20 MHz data) of the borehole radar measurement in KLX22A.*

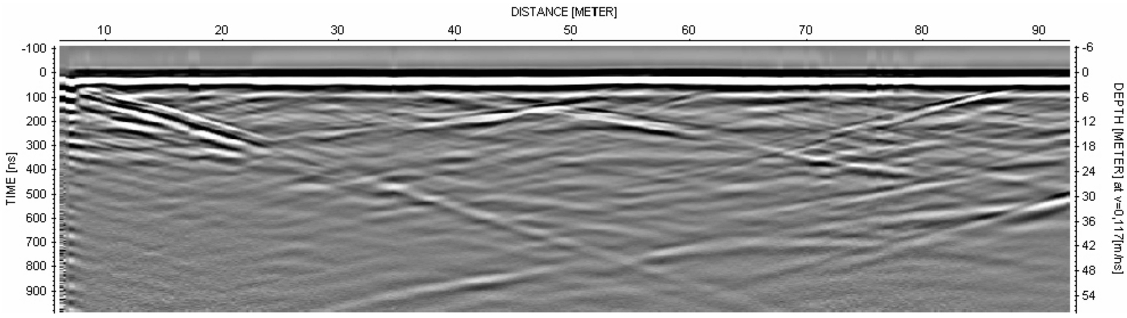


Figure 4-14. *Overview (20 MHz data) of the borehole radar measurement in KLX22B.*

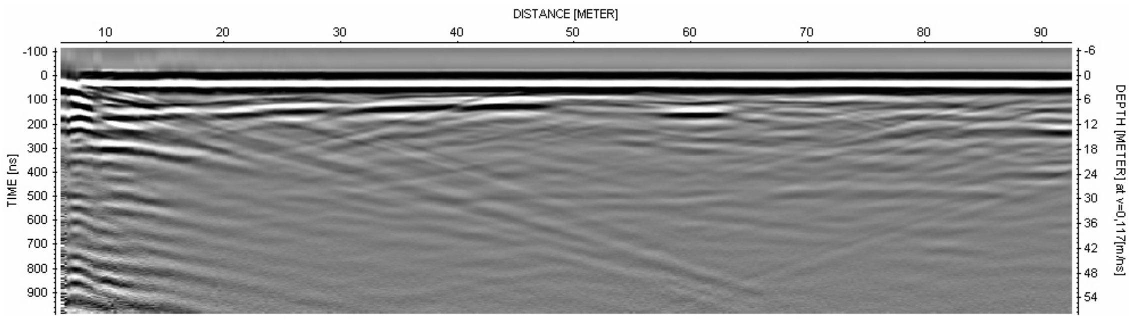


Figure 4-15. *Overview (20 MHz data) of the borehole radar measurement in KLX23A.*

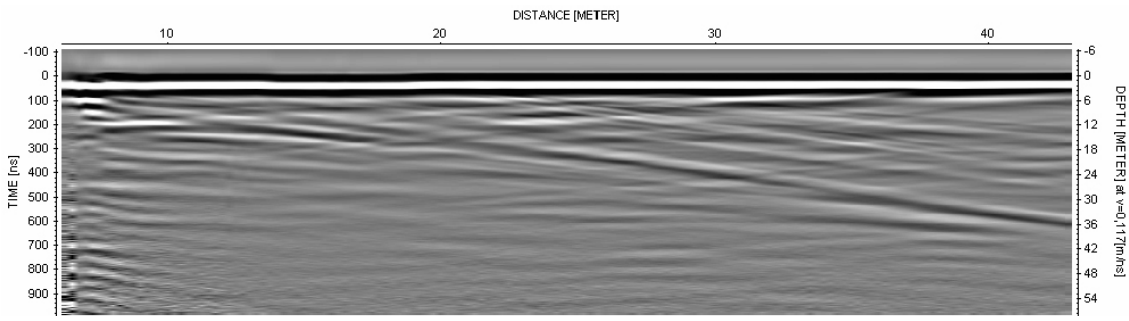


Figure 4-16. *Overview (20 MHz data) of the borehole radar measurement in KLX23B.*

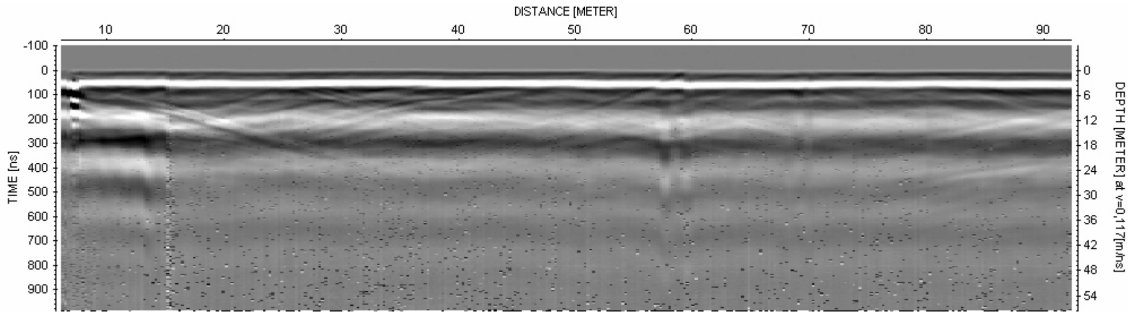


Figure 4-17. *Overview (20 MHz data) of the borehole radar measurement in KLX24A.*

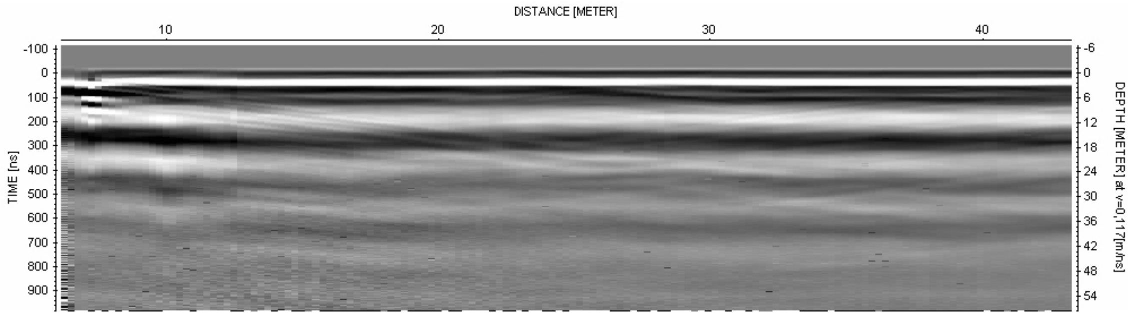


Figure 4-18. *Overview (20 MHz data) of the borehole radar measurement in KLX25A.*

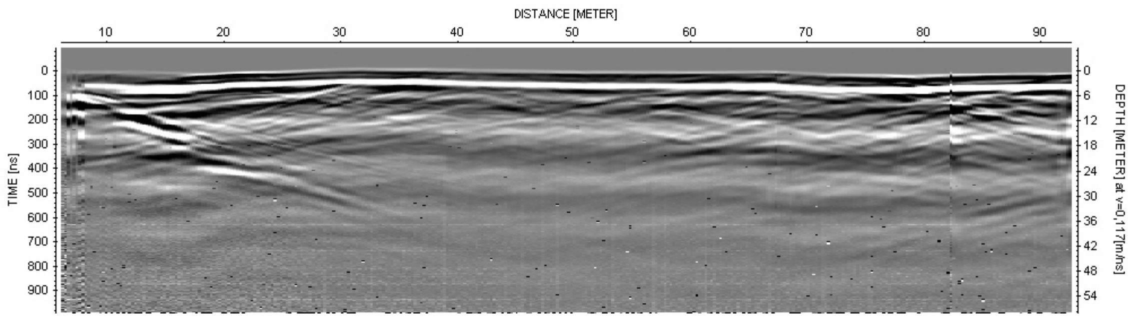


Figure 4-19. *Overview (20 MHz data) of the borehole radar measurement in KLX26A.*

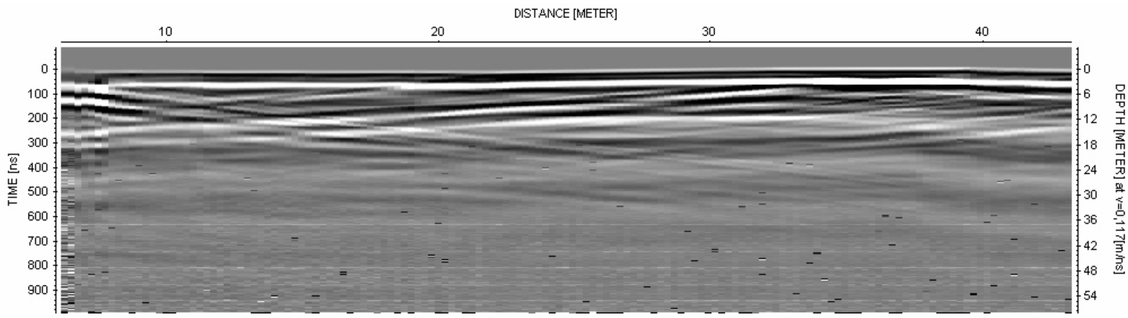


Figure 4-20. *Overview (20 MHz data) of the borehole radar measurement in KLX26B.*

5 Results

The detailed result of the single-hole interpretation is presented as print-out from the software WellCad (Appendices 1–8).

5.1 KLX22A

Rock units

The borehole consists of one rock unit.

4.00–100.37 m

RU1: Totally dominated by quartz monzodiorite (501036). Subordinate rock types comprise fine-grained granite (511058), particularly in the section 64–69 m, and fine-grained diorite-gabbro (505102), particularly in the section c 69–74 m. The quartz monzodiorite (501036) has a density in the range 2,750–2,800 kg/m^3, and a magnetic susceptibility in the range 0.015–0.025 SI. A major part of the rock unit is characterized by faint to moderate foliation. Confidence level = 3.

Possible deformation zones

One possible deformation zone has been recognised in KLX22A.

76.90–77.22 m

DZ1: Minor ductile to brittle-ductile shear zone with increased frequency of sealed fractures, medium red staining and saussuritization and aperture of open fractures. Low magnetic susceptibility, resistivity and P-wave velocity. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock types are fine-grained granite (511058). Confidence level = 3.

5.2 KLX22B

Rock units

The borehole consists of one rock unit (RU1).

4.00–100.07 m

RU1: Totally dominated by quartz monzodiorite (501036). Subordinate rock types comprise fine-grained granite (511058), particularly in the section 57–62 m, fine-grained diorite-gabbro (505102), particularly in the section c 62–63 m, Ävrö granite (501044), and very sparse occurrences of diorite/gabbro (501033), pegmatite (501061) and presumed sandstone (506007). The quartz monzodiorite (501036) has a density in the range 2,750–2,800 kg/m^3, and a magnetic susceptibility in the range 0.015–0.025 SI. Scattered up to c 20 m long sections are characterized by faint to weak foliation. Confidence level = 3.

Possible deformation zones

One possible deformation zone has been recognised in KLX22B.

22.00–25.00 m

DZ1: Brittle deformation zone characterized by increased frequency of open and sealed fractures, sealed network, minor core loss and crush, and weak to medium red staining, epidotization and saussuritization. Slickensides are documented. Low magnetic susceptibility, resistivity and P-wave velocity. One non-oriented radar reflector occurs at 22.6 m with the angle 32° to borehole axis and one oriented at 25.3 m (just outside the deformation zone) with the orientation 241/31. Both reflectors are medium strong and can be observed to a distance of 9 m outside the borehole. The host rock is dominated by quartz monzodiorite (501036). Confidence level = 3.

5.3 KLX23A

Rock units

The borehole consists of one rock unit (RU1).

4.00–99.96 m

RU1: Totally dominated by quartz monzodiorite (501036). Subordinate rock types comprise fine-grained granite (511058) and very sparse occurrence of pegmatite (501061). The quartz monzodiorite (501036) has a density in the range 2,720–2,770 kg/m^3, and a magnetic susceptibility in the range 0.020–0.030 SI. Scattered up to c 15 m long sections, that make up c 50% of the borehole, are characterized by faint and locally weak foliation. Confidence level = 3.

Possible deformation zones

Two possible deformation zones have been recognised in KLX23A.

10.75–11.75 m

DZ1: Brittle deformation zone characterized by increased frequency of sealed fractures and a slight increase in open fractures and faint red staining. Low magnetic susceptibility. There is very low radar amplitude from the start of the borehole to 15 m. Two non-oriented radar reflectors occur at 11.4 m and 11.7 m with the angle 61° and 77° to borehole axis, respectively. The latter reflector is strong and can be observed to a distance of 30 m outside the borehole. The host rock is dominated by quartz monzodiorite (501036) and fine-grained granite (511058). Confidence level = 3.

15.66–16.70 m

DZ2: Brittle deformation zone characterized by increased frequency of sealed and open fractures and weak red staining. Low magnetic susceptibility, resistivity and P-wave velocity. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock is fine-grained granite (511058). Confidence level = 3.

5.4 KLX23B

Rock units

The borehole consists of one rock unit (RU1).

4.00–50.25 m

RU1: Totally dominated by quartz monzodiorite (501036). Subordinate rock types comprise fine-grained granite (511058), Ävrö granite (501044) and very sparse occurrence of granite (501058). The quartz monzodiorite (501036) has a density in the range 2,720–2,770 kg/m^3, and a magnetic susceptibility in the range 0.020–0.025 SI. Scattered up to c 15 m long sections are characterized by faint foliation. Confidence level = 3.

Possible deformation zones

One possible deformation zone has been recognised in KLX23B.

13.30–14.80 m

DZ1: Brittle deformation zone characterized by increased frequency of sealed and open fractures, brecciation, apertures in open fractures and medium red staining and weak epidotization. Slickensides are documented. Low magnetic susceptibility, resistivity and P-wave velocity. One non-oriented radar reflector occurs at 13.8 m with the angle 60° to borehole axis. The reflector can be observed to a distance of 4 m outside the borehole. There is very low radar amplitude at 13–15 m. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock is fine-grained granite (511058). Confidence level = 3.

5.5 KLX24A

Rock units

The borehole consists of one rock unit (RU1).

4.00–99.81 m

RU1: Totally dominated by quartz monzodiorite (501036). Subordinate rock types comprise fine-grained granite (511058), particularly in the section c 31–36 m, pegmatite (501061), diorite/gabbro (501033), and very sparse occurrences of granite (501058) and presumed sandstone (506007). The quartz monzodiorite (501036) has a density in the range 2,750–2,800 kg/m^3, and a magnetic susceptibility in the range 0.020–0.040 SI. Scattered minor sections are characterized by faint to moderate foliation, particularly the fine-grained granite (511058) in the section c 31–36 m. Confidence level = 3.

Possible deformation zones

Four possible deformation zones have been recognised in KLX24A.

19.75–21.20 m

DZ1: Brittle deformation zone characterized by increased frequency of sealed and open fractures, faint red staining, minor crush and slickensides. Low magnetic susceptibility, resistivity and P-wave velocity, two caliper anomalies. Two non-oriented radar reflectors at 20.2 m and 21.4 m with the angle 18° and 63° to borehole axis, respectively. The reflectors can be observed to a distance of 2 m outside the borehole. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock types are pegmatite (501061) and fine-grained granite (511058). Confidence level = 3.

56.75–60.25 m

DZ2: Ductile deformation zone with increased frequency of sealed and open fractures, weak red staining and saussuritization, and slickensides. Low magnetic susceptibility. One non-oriented radar reflector occurs at 56.7 m with the angle 47° to borehole axis. The reflector can be observed to a distance of 3 m outside the borehole. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock types are pegmatite (501061) and fine-grained granite (511058). Confidence level = 3.

64.65–66.60 m

DZ3: Brittle-ductile shear zone with increased frequency of both sealed and open fractures, minor crush and core loss, weak red staining and slickensides. Low magnetic susceptibility, resistivity and P-wave velocity, one caliper anomaly. One non-oriented radar reflector occurs at 65.6 m with the angle 82° to borehole axis and one radar reflector occurs at 64.1 m with the orientation 191/17. The oriented radar reflector can be observed to a distance of 9 m outside the borehole. Low radar amplitude at 63–66 m. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock types are pegmatite (501061) and fine-grained granite (511058). Confidence level = 3.

75.25–75.75 m

DZ4: Brittle deformation zone, brecciated with increased frequency of sealed fractures, apertures in some open fractures and weak red staining. Low magnetic susceptibility, resistivity and P-wave velocity. Two non-oriented radar reflectors at 73.4 m and 75.3 m with the angle 26° and 45° to borehole axis, respectively. One oriented radar reflector occurs at 74.4 m with the orientation 224/50 or 122/38. The oriented radar reflector can be observed to a distance of 9 m outside the borehole. Decreased radar amplitude at 74–76 m. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock type is pegmatite (501061). Confidence level = 3.

5.6 KLX25A

Rock units

The borehole consists of one rock unit (RU1).

4.00–50.10 m

RU1: Totally dominated by quartz monzodiorite (501036). Subordinate rock types comprise fine-grained granite (511058), and very sparse occurrences of pegmatite (501061) and fine-grained diorite-gabbro (505102). The quartz monzodiorite (501036) has a density in the range 2,740–2,790 kg/m^3, and a magnetic susceptibility in the range 0.015–0.025 SI. A few minor sections are characterized by faint to moderate foliation. Confidence level = 3.

Possible deformation zones

One possible deformation zone has been recognised in KLX25A.

32.10–35.66 m

DZ1: Brittle-ductile shear zone, moderately foliated with increased frequency of sealed and open fractures, apertures in open fractures, faint to weak red staining and weak carbonatization. Low magnetic susceptibility. One non-oriented radar reflector occurs at 34.3 m with the angle 61° to borehole axis. The reflector can be observed to a distance of 5 m outside the borehole. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock type is fine-grained granite (511058). Confidence level = 3.

5.7 KLX26A

Rock units

The borehole consists of two rock units (RU1–RU2). Due to repetition of RU1 (RU1a and RU1b) the borehole can be divided into three sections.

4.00–26.43 m

RU1a: Totally dominated by diorite/gabbro (501033). Subordinate rock types comprise Ävrö granite (501044), fine-grained granite (511058) and minor occurrences of pegmatite (501061) and granite (501058). The diorite/gabbro (501033) has a density in the range 2,920–3,020 kg/m^3, and a magnetic susceptibility in the range 0.005–0.120 SI. Confidence level = 3.

26.43–45.69 m

RU2: Totally dominated by fine-grained granite (511058). Subordinate rock types comprise Ävrö granite (501044), pegmatite (501061) and diorite/gabbro (501033). The rock unit is characterized by weak foliation and increased frequency of open fractures. Confidence level = 3.

45.69–99.93 m

RU1b: Totally dominated by diorite/gabbro (501033). Subordinate rock types comprise quartz monzodiorite (501036), Ävrö granite (501044), fine-grained diorite-gabbro (505102), particularly in the lower part of the rock unit, fine-grained granite (511058) and minor occurrence of pegmatite (501061). The diorite/gabbro (501033) has a density in the range 2,920–3,100 kg/m^3, and a magnetic susceptibility in the range 0.005–0.120 SI. Confidence level = 3.

Possible deformation zones

Four possible deformation zones have been recognised in KLX26A.

17.45–18.10 m

DZ1: Brittle-ductile shear zone, brecciated, with increased frequency of open and sealed fractures, weak epidotization. Low magnetic susceptibility, resistivity and P-wave velocity. One strong radar reflector occurs at 18.6 m with the orientation 121/69 or 264/52. The reflector can be observeded to a distance of 6 m outside the borehole. The host rock is dominated by diorite/gabbro (501033). Subordinate rock type is pegmatite (501061). Confidence level = 3.

42.60–54.80 m

DZ2: Inhomogeneous brittle-ductile shear zone, partly weakly foliated, with increased frequency of sealed and open fractures, faint red staining and weak epidotization. Low magnetic susceptibility and frequent minor resistivity anomalies. Four non-oriented radar reflectors occur with angles between 26° to 66° to borehole axis. Two oriented radar reflectors occur at 42.2 m with the orientation 122/17 or 200/52 and at 47.4 m with the orientation 103/73. The first one can be observeded to a distance of 18 m outside the borehole and the latter to a distance of 10 m outside the borehole. The host rock is dominated by diorite/gabbro (501033) and fine-grained granite (511058). Subordinate rock types are pegmatite (501061), fine-grained granite (511058) and very sparse quartz monzodiorite (501036). Confidence level = 3.

72.30–73.95 m

DZ3: Brittle-ductile shear zone, brecciated, with increased frequency of open and sealed fractures, weak epidotization and crush. Low magnetic susceptibility, resistivity and P-wave velocity, and one caliper anomaly. One rather strong radar reflector occurs at 73.6 m with the orientation 104/32. The reflector can be traced to a distance of 10 m outside the borehole. The host rock is dominated by diorite/gabbro (501033). Subordinate rock type is fine-grained granite (511058). Confidence level = 3.

97.30–99.80 m

DZ4: Ductile shear zone with increased frequency of open and sealed fractures and minor crush. Low magnetic susceptibility, resistivity and P-wave velocity. One non-oriented radar reflector occurs at 99.1 m with the angle 43° to borehole axis. The host rock is dominated by fine-grained diorite to gabbro (505102). Subordinate rock types are quartz monzodiorite (501036) and Ävrö granite (501044). Confidence level = 3.

5.8 KLX26B

Rock units

The borehole consists of two rock units (RU1–RU2). Due to repetition of RU1 (RU1a and RU1b) the borehole can be divided into three sections.

4.00–27.49 m

RU1a: Totally dominated by diorite/gabbro (501033). Subordinate rock types comprise fine-grained granite (511058) and pegmatite (50061). The diorite/gabbro (501033) has a density in the range 2,920–2,990 kg/m^3, and a magnetic susceptibility in the range 0.005–0.030 SI. Confidence level = 3.

27.49–44.86 m

RU2: Totally dominated by fine-grained granite (511058). The rock unit is characterized by faint foliation and increased frequency of open and sealed fractures. Confidence level = 3.

44.86–50.30 m

RU1b: Totally dominated by diorite/gabbro (501033). Subordinate rock types comprise fine-grained granite (511058) and pegmatite (50061). The diorite/gabbro (501033) has a density in the range 2,920–3,080 kg/m^3, and a magnetic susceptibility in the range 0.020–0.100 SI. Confidence level = 3.

Possible deformation zones

No possible deformation zones have been recognised in KLX26B.

6 Comments

The results from the geological single-hole interpretation of KLX22A–B, KLX23A–B, KLX24A, KLX25A and KLX26A–B are presented in a WellCad plot (Appendices 1–8). The WellCad plot consists of the following columns:

In data Boremap	1: Depth (Length along the borehole)
	2: Rock type
	3: Rock alteration
	4: Frequency of sealed fractures
	5: Frequency of open and partly open fractures
	6: Crush zones
In data Geophysics	7: Silicate density
	8: Magnetic susceptibility
	9: Natural gamma radiation
	10: Estimated fracture frequency
Interpretations	11: Description: Rock unit
	12: Stereogram for sealed fractures in rock unit (blue symbols)
	13: Stereogram for open and partly open fractures in rock unit (red symbols)
	14: Description: Possible deformation zone
	15: Stereogram for sealed fractures in possible deformation zone (blue symbols)
	16: Stereogram for open and partly open fractures in possible deformation zone (red symbols)

7 References

/1/ **Munier R, Stenberg L, Stanfors R, Milnes A G, Hermanson J, Triumf CA, 2003.** Geological site descriptive model. A strategy for the model development during site investigations. SKB R-03-07, Svensk Kärnbränslehantering AB.

/2/ **Mattsson K-J, Eklund S, Ehrenborg J, 2006.** Oskarshamn site investigation. Boremap mapping of core drilled MDZ boreholes KLX22A, KLX22B, KLX23A and KLX23B. SKB P-06-243, Svensk Kärnbränslehantering AB.

/3/ **Mattsson K-J, Rauséus G, Ehrenborg J, 2006.** Oskarshamn site investigation. Boremap mapping of core drilled MDZ boreholes KLX24A and KLX25A. SKB P-06-257, Svensk Kärnbränslehantering AB.

/4/ **Mattsson K-J, Rauséus G, Ehrenborg J, 2006.** Oskarshamn site investigation. Boremap mapping of core drilled MDZ boreholes KLX26A and KLX26B. SKB P-06-256, Svensk Kärnbränslehantering AB.

/5/ **Mattsson H, Keisu M, 2006.** Oskarshamn site investigation. Interpretation of geophysical borehole measurements from KLX13A, KLX14A, KLX22A, KLX22B, KLX23A, KLX23B, KLX24A, KLX25A, KLX26A and KLX26B. SKB P-06-317, Svensk Kärnbränslehantering AB.

/6/ **Gustafsson J, Gustafsson C, 2006.** Oskarshamn site investigation. RAMAC, BIPS and deviation logging in boreholes KLX13A, KLX14A, KLX22A, KLX22B, KLX23A, KLX23B, KLX24A, KLX25A, KLX26A, KLX26B, HLX39 and HLX41. SKB P-06-260, Svensk Kärnbränslehantering AB.

Geological single-hole interpretation of KLX22A

Title	SINGLE HOLE INTERPRETATION KLX22A					
Site	LAXEMAR	Inclination [°]	-60.33	Elevation [m.a.s.l.]	21.90	Signed data
Borehole	KLX22A	Date of mapping	2006-06-29 16:54:00	Drilling Start Date	2006-05-05 12:00:00	
Diameter [mm]	76	Coordinate System	RT90-RHB70	Drilling Stop Date	2006-05-12 13:40:00	
Length [m]	100.450	Northing [m]	6366547.53	Surveying Date		
Bearing [°]	179.19	Easting [m]	1546688.64	Plot Date	2007-10-14 22:03:05	

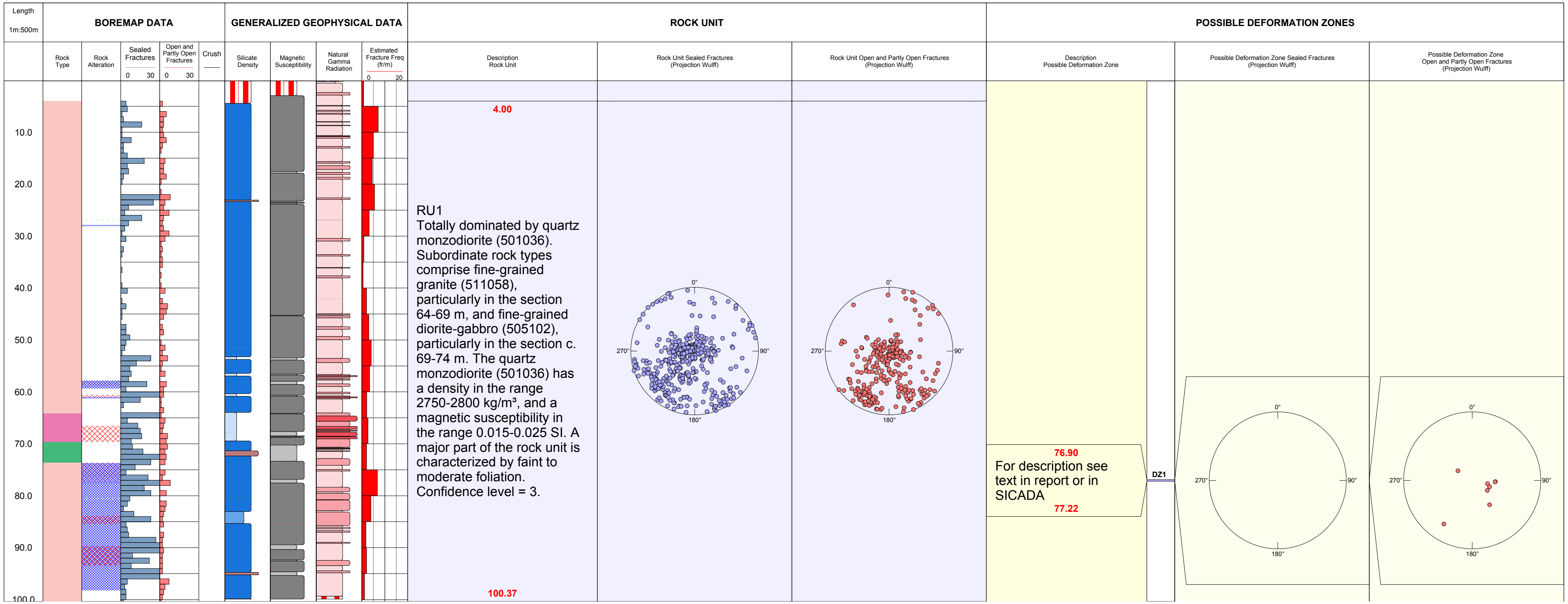
ROCKTYPE LAXEMAR
- Fine-grained granite
- Quartz monzodiorite
- Fine-grained diorite-gabbro

ROCK ALTERATION
- Oxidized
- Epidotisized
- Saussuritization

SILICATE DENSITY
- unclassified
- dens<2680
- 2680<dens<2730
- 2730<dens<2800
- 2800<dens<2890

SUSCEPTIBILITET
- unclassified
- 0.001<sus<0.01
- 0.01<sus<0.1

NATURAL GAMMA
- unclassified
- gam<10
- 10<gam<20
- 20<gam<30
- gam>30



Geological single-hole interpretation of KLX22B

Title	SINGLE HOLE INTERPRETATION KLX22B					
Site	LAXEMAR	Inclination [°]	-61.24	Elevation [m.a.s.l.]	21.51	Signed data
Borehole	KLX22B	Date of mapping	2006-06-29 16:55:00	Drilling Start Date	2006-05-13 09:13:00	
Diameter [mm]	76	Coordinate System	RT90-RHB70	Drilling Stop Date	2006-05-18 13:03:00	
Length [m]	100.250	Northing [m]	6366552.31	Surveying Date		
Bearing [°]	343.97	Easting [m]	1546685.45	Plot Date	2007-10-14 22:03:05	

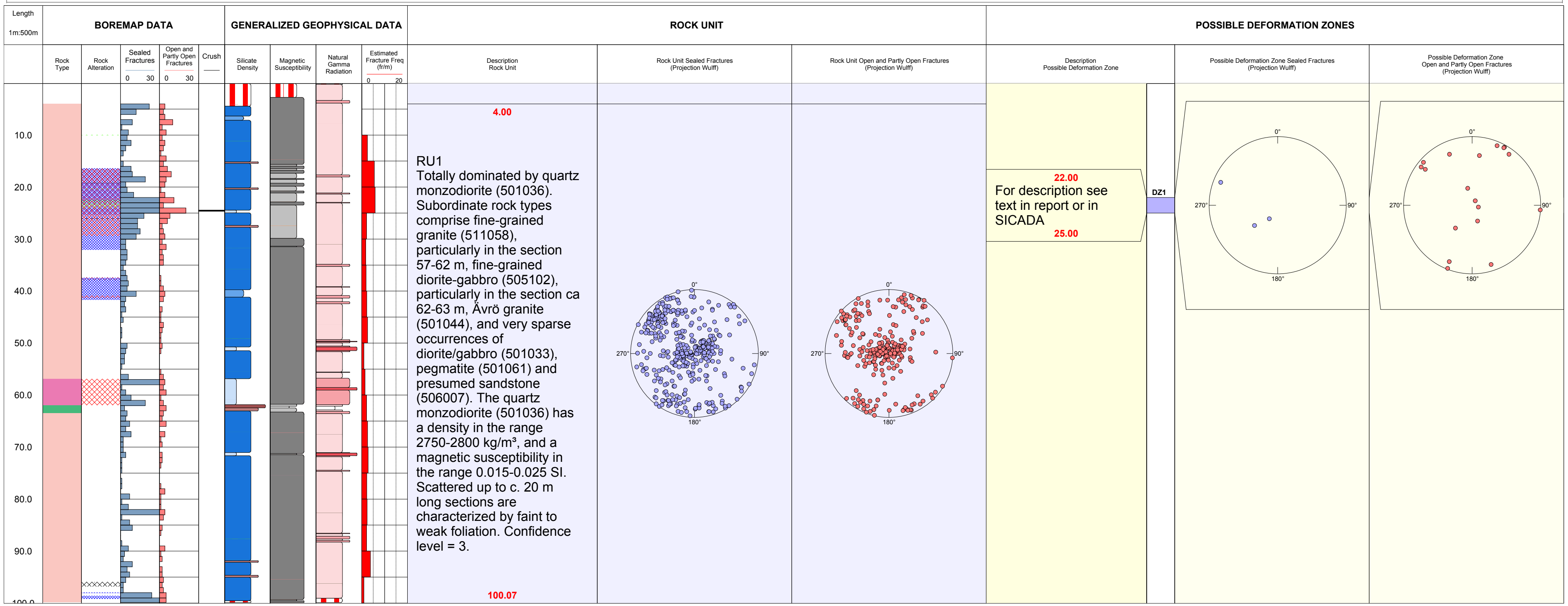
ROCKTYPE LAXEMAR
- Fine-grained granite
- Quartz monzodiorite
- Fine-grained diorite-gabbro

ROCK ALTERATION
- Oxidized
- Epidotisized
- Silicification
- Saussuritization

SILICATE DENSITY
- unclassified
- dens<2680
- 2680<dens<2730
- 2730<dens<2800
- 2800<dens<2890
- dens>2890

SUSCEPTIBILITET
- unclassified
- sus<0.001
- 0.001<sus<0.01
- 0.01<sus<0.1

NATURAL GAMMA
- unclassified
- gam<10
- 10<gam<20
- 20<gam<30
- gam>30



Geological single-hole interpretation of KLX23A

Title	SINGLE HOLE INTERPRETATION KLX23A					
Site	LAXEMAR	Inclination [°]	-61.35	Elevation [m.a.s.l.]	22.19	Signed data
Borehole	KLX23A	Date of mapping	2006-07-25 07:14:00	Drilling Start Date	2006-05-21 10:27:00	
Diameter [mm]	76	Coordinate System	RT90-RHB70	Drilling Stop Date	2006-05-27 07:45:00	
Length [m]	100.150	Northing [m]	6366106.07	Surveying Date		
Bearing [°]	28.73	Easting [m]	1546715.79	Plot Date	2007-10-14 22:03:05	

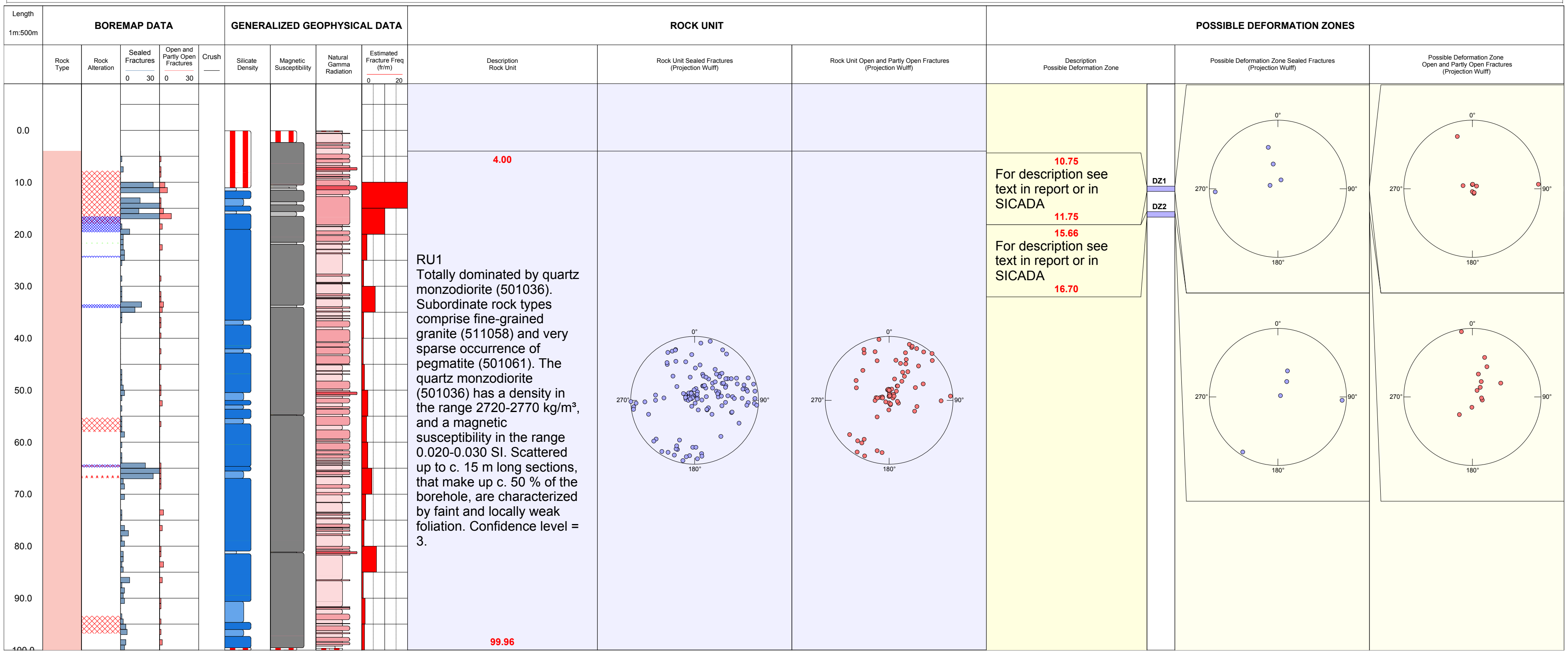
ROCKTYPE LAXEMAR
- Quartz monzodiorite

ROCK ALTERATION
- Oxidized
- Epidotisized
- Saussuritization

SILICATE DENSITY
- unclassified
- dens<2680
- 2680<dens<2730
- 2730<dens<2800

SUSCEPTIBILITET
- unclassified
- sus<0.001
- 0.001<sus<0.01
- 0.01<sus<0.1

NATURAL GAMMA
- unclassified
- gam<10
- 10<gam<20
- 20<gam<30
- gam>30



Geological single-hole interpretation of KLX23B

Title	SINGLE HOLE INTERPRETATION KLX23B					
Site	LAXEMAR	Inclination [°]	-60.84	Elevation [m.a.s.l.]	22.25	Signed data
Borehole	KLX23B	Date of mapping	2006-07-24 08:47:00	Drilling Start Date	2006-05-28 13:55:00	
Diameter [mm]	76	Coordinate System	RT90-RHB70	Drilling Stop Date	2006-05-31 11:15:00	
Length [m]	50.270	Northing [m]	6366101.08	Surveying Date		
Bearing [°]	121.36	Easting [m]	1546717.38	Plot Date	2007-10-14 22:03:05	

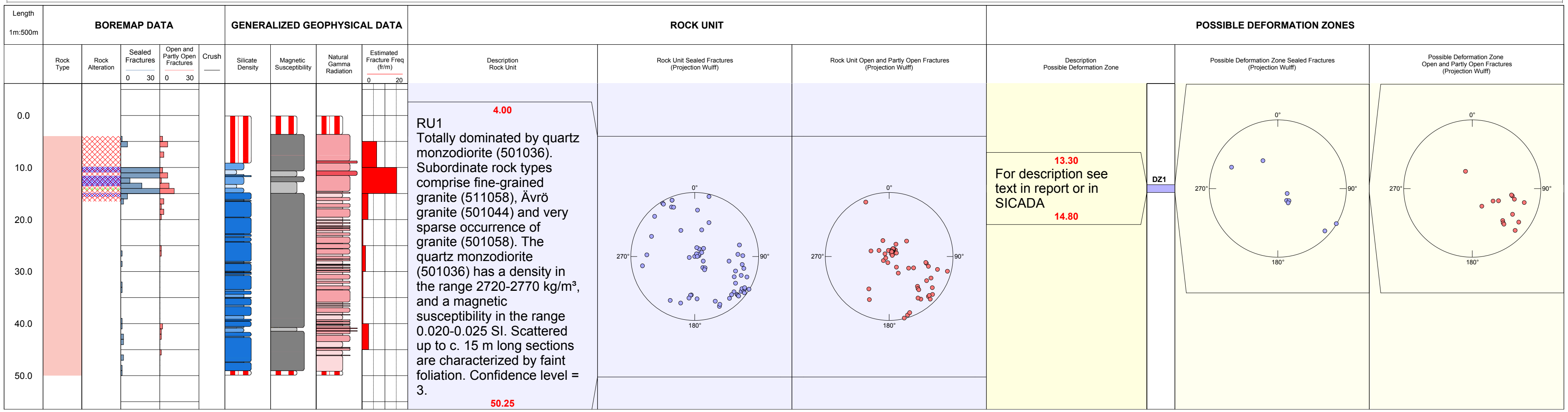
ROCKTYPE LAXEMAR
- Quartz monzodiorite

ROCK ALTERATION
- Oxidized
- Chloritisized
- Epidotisized
- Saussuritization

SILICATE DENSITY
- unclassified
- dens<2680
- 2680<dens<2730
- 2730<dens<2800

SUSCEPTIBILITET
- unclassified
- 0.001<sus<0.01
- 0.01<sus<0.1

NATURAL GAMMA
- unclassified
- 10<gam<20
- 20<gam<30
- gam>30



Geological single-hole interpretation of KLX24A

Title SINGLE HOLE INTERPRETATION KLX24A

Site	LAXEMAR	**Inclination [°]**	-59.14	**Elevation [m.a.s.l.]**	21.26	**Signed data**
Borehole	KLX24A	**Date of mapping**	2006-08-14 12:13:00	**Drilling Start Date**	2006-06-14 11:00:00	
Diameter [mm]	76	**Coordinate System**	RT90-RHB70	**Drilling Stop Date**	2006-06-29 08:45:00	
Length [m]	100.170	**Northing [m]**	6854.45	**Surveying Date**		
Bearing [°]	110.23	**Easting [m]**	-2625.75	**Plot Date**	2007-10-14 22:03:05	

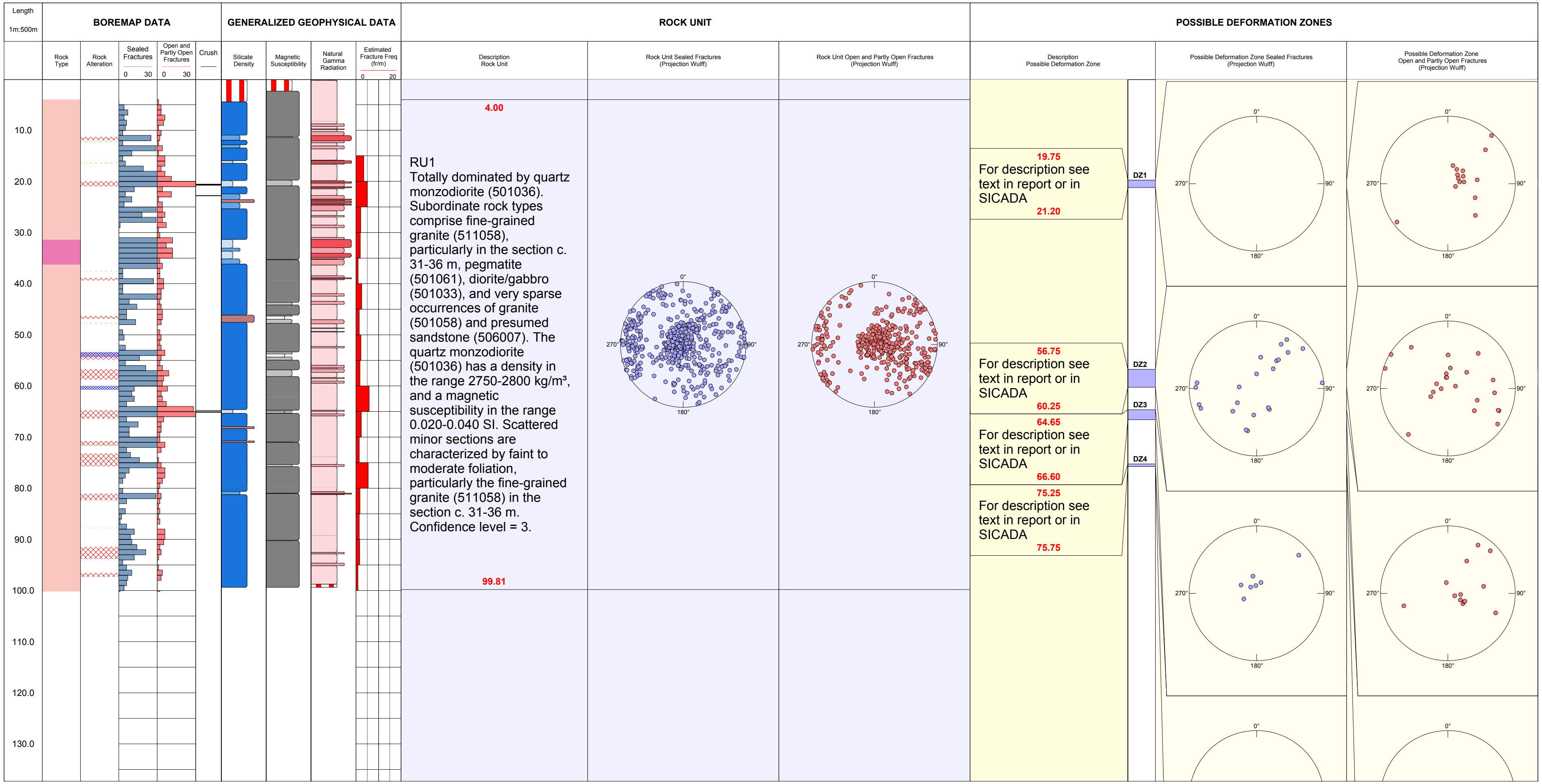
ROCKTYPE LAXEMAR
- Fine-grained granite
- Quartz monzodiorite

ROCK ALTERATION
- Oxidized
- Epidotisized
- Argillization
- Saussuritization

SILICATE DENSITY
- unclassified
- dens<2680
- 2680<dens<2730
- 2730<dens<2800
- 2800<dens<2890

SUSCEPTIBILITET
- unclassified
- sus<0.001
- 0.001<sus<0.01
- 0.01<sus<0.1

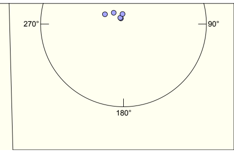
NATURAL GAMMA
- unclassified
- 10<gam<20
- 20<gam<30
- gam>30

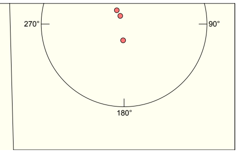


140.0

150.0

160.0





Geological single-hole interpretation of KLX25A

Title	SINGLE HOLE INTERPRETATION KLX25A					
Site	LAXEMAR	Inclination [°]	-59.45	Elevation [m.a.s.l.]	22.77	Signed data
Borehole	KLX25A	Date of mapping	2006-08-14 13:30:00	Drilling Start Date	2006-07-01 14:00:00	
Diameter [mm]	76	Coordinate System	RT90-RHB70	Drilling Stop Date	2006-07-04 14:00:00	
Length [m]	50.240	Northing [m]	6366273.92	Surveying Date		
Bearing [°]	145.73	Easting [m]	1546769.71	Plot Date	2007-10-14 22:03:05	

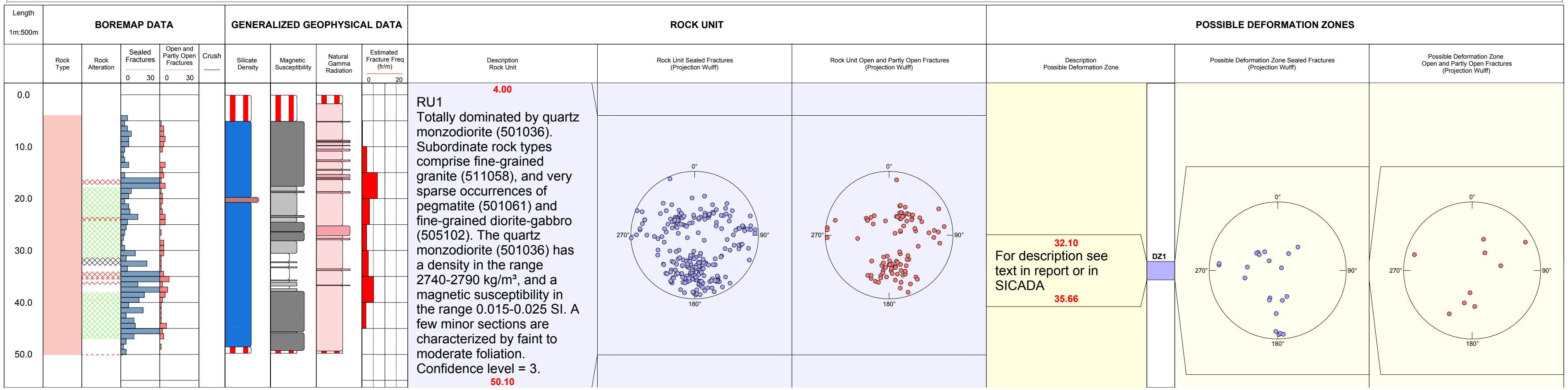
ROCKTYPE LAXEMAR
- Quartz monzodiorite

ROCK ALTERATION
- Oxidized
- Epidotisized
- Carbonatization

SILICATE DENSITY
- unclassified
- 2730<dens<2800
- 2800<dens<2890

SUSCEPTIBILITET
- unclassified
- sus<0.001
- 0.001<sus<0.01
- 0.01<sus<0.1

NATURAL GAMMA
- unclassified
- 10<gam<20
- 20<gam<30



Geological single-hole interpretation of KLX26A

Title SINGLE HOLE INTERPRETATION KLX26A

Site	LAXEMAR	**Inclination [°]**	-60.44	**Elevation [m.a.s.l.]**	15.60	**Signed data**	
Borehole	KLX26A	**Date of mapping**	2006-09-05 18:33:00	**Drilling Start Date**	2006-08-03 06:00:00		
Diameter [mm]	76	**Coordinate System**	RT90-RHB70	**Drilling Stop Date**	2006-08-11 11:00:00		
Length [m]	101.140	**Northing [m]**	5550.35	**Surveying Date**			
Bearing [°]	105.29	**Easting [m]**	-675.47	**Plot Date**	2007-10-14 22:03:05		

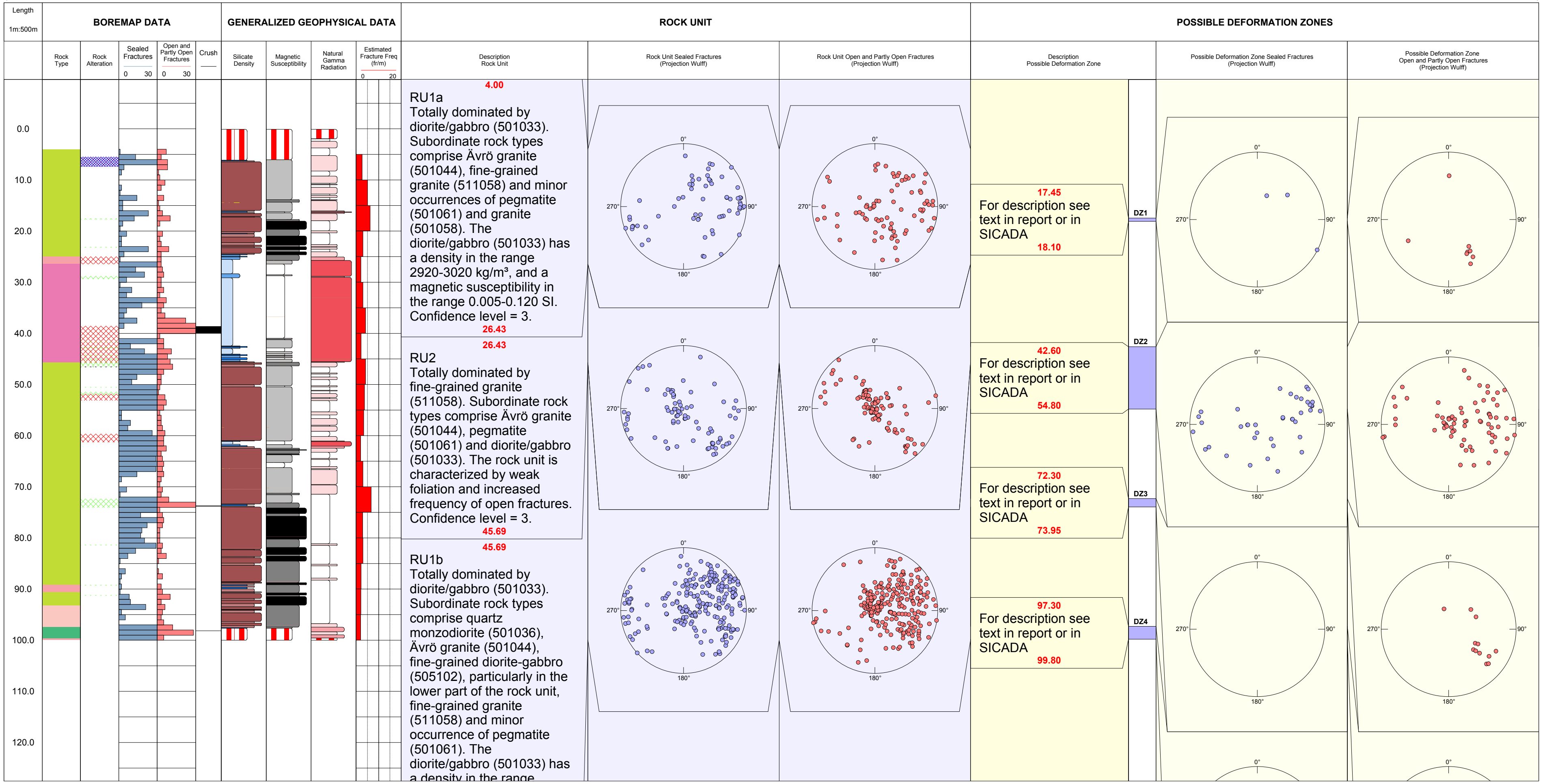
ROCKTYPE LAXEMAR
- Fine-grained granite
- Ävrö granite
- Quartz monzodiorite
- Diorite / Gabbro
- Fine-grained diorite-gabbro

ROCK ALTERATION
- Oxidized
- Epidotisized
- Carbonatization
- Saussuritization

SILICATE DENSITY
- unclassified
- dens<2680
- 2680<dens<2730
- 2730<dens<2800
- 2800<dens<2890
- dens>2890

SUSCEPTIBILITET
- unclassified
- sus<0.001
- 0.001<sus<0.01
- 0.01<sus<0.1
- sus>0.1

NATURAL GAMMA
- unclassified
- gam<10
- 10<gam<20
- 20<gam<30
- gam>30



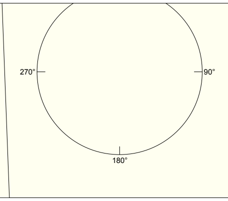
130.0

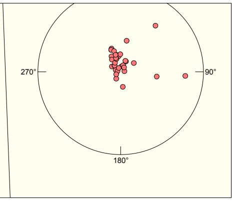
140.0

150.0

a density in the range 2920-3100 kg/m³, and a magnetic susceptibility in the range 0.005-0.120 SI. Confidence level = 3.

99.93





Appendix 8

Geological single-hole interpretation of KLX26B

Title	SINGLE HOLE INTERPRETATION KLX26B					
Site	LAXEMAR	Inclination [°]	-60.00	Elevation [m.a.s.l.]	15.75	Signed data
Borehole	KLX26B	Date of mapping	2006-09-13 09:19:00	Drilling Start Date	2006-08-12 09:00:00	
Diameter [mm]	76	Coordinate System	RT90-RHB70	Drilling Stop Date	2006-08-17 07:15:00	
Length [m]	50.370	Northing [m]	6365549.84	Surveying Date		
Bearing [°]	137.42	Easting [m]	1549025.66	Plot Date	2007-10-14 22:03:05	

ROCKTYPE LAXEMAR
- Fine-grained granite
- Diorite / Gabbro

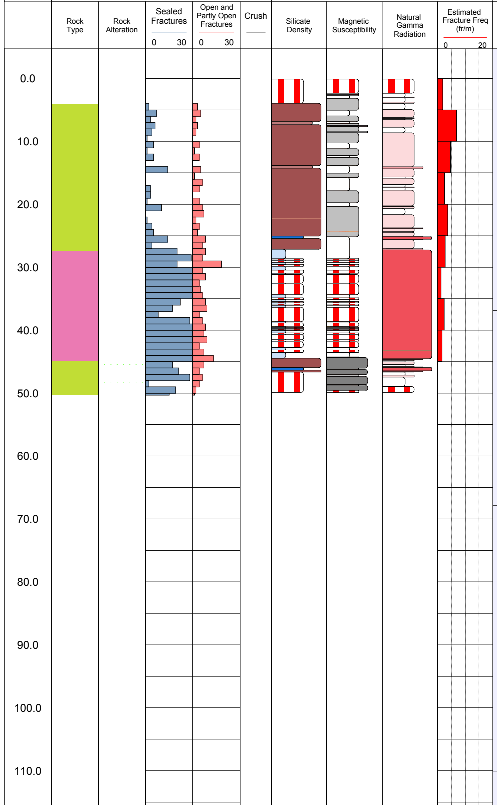
ROCK ALTERATION
- Epidotisized

SILICATE DENSITY
- unclassified
- dens<2680
- 2730<dens<2800
- 2800<dens<2890
- dens>2890

SUSCEPTIBILITET
- unclassified
- sus<0.001
- 0.001<sus<0.01
- 0.01<sus<0.1

NATURAL GAMMA
- unclassified
- gam<10
- 10<gam<20
- 20<gam<30
- gam>30

Length 1m:500m	BOREMAP DATA	GENERALIZED GEOPHYSICAL DATA	ROCK UNIT	POSSIBLE DEFORMATION ZONES



Description Rock Unit

4.00

RU1a
Totally dominated by diorite/gabbro (501033). Subordinate rock types comprise fine-grained granite (511058) and pegmatite (50061). The diorite/gabbro (501033) has a density in the range 2920-2990 kg/m³, and a magnetic susceptibility in the range 0.005-0.030 SI. Confidence level = 3.

27.49

27.49

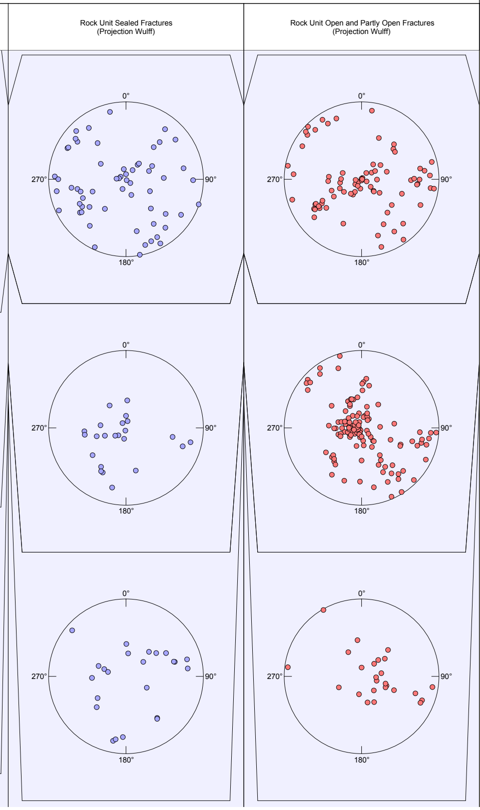
RU2
Totally dominated by fine-grained granite (511058). The rock unit is characterized by faint foliation and increased frequency of open and sealed fractures. Confidence level = 3.

44.86

44.86

RU1b
Totally dominated by diorite/gabbro (501033). Subordinate rock types comprise fine-grained granite (511058) and pegmatite (50061). The diorite/gabbro (501033) has a density in the range 2920-3080 kg/m³, and a magnetic susceptibility in the range 0.020-0.100 SI. Confidence level = 3.

50.30



Description Possible Deformation Zone	Possible Deformation Zone Sealed Fractures (Projection Wulff)	Possible Deformation Zone Open and Partly Open Fractures (Projection Wulff)